Neutron Detector R&D Roadmap

Ron Cooper

SNS Detector Team Leader

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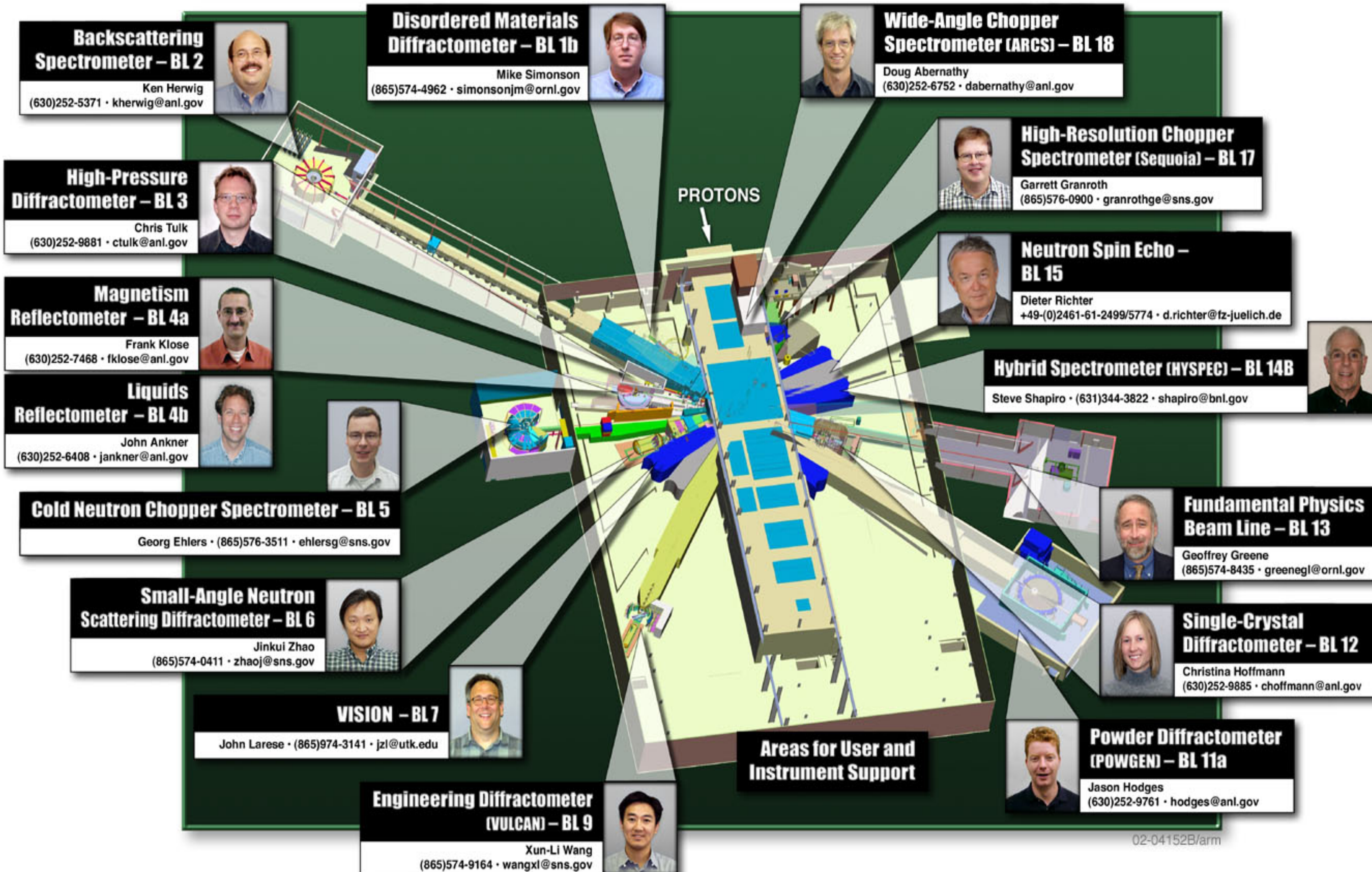
Roadmap Components

- Science case
  - Presented by Lowell Crow
- Instrument requirements
  - 24 beam lines in high power target station
  - 14 approved instruments
- Detector deficiencies
  - Almost all instruments need better detectors
- Detector R&D
  - SNS driven at present
  - Prototype development
  - Education and outreach

Roadmap Components (2)

- Management plan
  - Maintain science focus
  - Communication and coordination
  - Organize pool of expertise, provide reviews and direction
  - Maintain whitepaper: http://www.sns.gov/documentation/
  - Neutron_Detector_White_Paper_March_03.pdf

Instruments



Component 2: Instrument Requirements

Table 3. Instrument requirements

Instrument	Number of pixels	Pixel area (cm^2)	Maximum neutron energy (eV)	Neutron capture efficiency %	Gamma efficiency	Time resolution (μs)	Peak pixel count rate ($n.s^{-1}$)	Detector count rate ($n.s^{-1}$)	Data transfer rate (Mb/s)
Powder Diffractometer	40,000	2.4	0.33	50	10^{-6}	1	100	3.5×10^6	28
Disordered Materials Diffractometer	150,000	0.25	50	20	10^{-6}	1	300	4.2×10^7	340
High-Pressure Diffractometer	100,000	0.02	0.5	50	10^{-7}	1	1×10^4	3.0×10^5	2.4
Engineering Diffractometer	80,000	1.25	0.15	50	10^{-6}	1	2×10^5	2.4×10^6	20
Single-Crystal Diffractometer	5×10^6	0.01	0.35	50	10^{-6}	10	2×10^4	3.0×10^5	2.4
SANS Diffractometer	40,000	0.25	0.08	50	10^{-7}	10	1,500	2.0×10^7	160
Liquids Reflectometer	40,000	0.01	0.02	50	10^{-7}	10	1×10^6	7.0×10^7	560
Magnetism Reflectometer	40,000	0.01	0.03	50	10^{-7}	10	1×10^6	9.0×10^7	720
Backscattering Spectrometer	4,500	1.3	0.01	50	10^{-6}	1	1×10^4	1.3×10^5	1
ARC Spectrometer	70,000	2.5	1.0	50	10^{-7}	1	1×10^6 (Bragg)	5.0×10^5	4
CNC Spectrometer	15,000	6.3	0.05	50	10^{-7}	1	1×10^6 (Bragg)	7.0×10^6	56
HRC Spectrometer	70,000	2.5	1.0	50	10^{-7}	1	1×10^6 (Bragg)	4.0×10^5	3.2

Critical Requirements

- Powder Diffractometer
  - Large area coverage > 10 m^2 when completed
  - 6 mm x 40 mm pixels
  - 50% efficiency for 325 meV, 0.5 Å neutrons
- Disordered Materials Diffractometer
  - Large area coverage > 5 m^2 when completed
  - 20% efficiency for 50 eV neutrons
  - Long term stability
- High Pressure Instrument
  - Low gamma sensitivity
  - Position resolution: 1.5mm x 1.5mm
  - Continuous coverage

Critical Requirements (2)

- Engineering Instrument
  - Large area coverage > 10 m^2 when completed
  - Maximum pixel rate: 20 n in 100 μs from elastic peaks
  - 100 μm resolution residual stress detector
- Single Crystal Diffractometer
  - 1-mm resolution
  - High dynamic range with minimal pixel cross talk
  - Maximum rate: 2×10^4 N per second per peak, 2000 peaks
- SANS Instrument
  - Maximum rate: 2×10^7 N per second
  - Low gamma sensitivity
  - 50% efficiency for 80 meV neutrons

Critical Requirements (3)

- Liquids and Magnetism Reflectometers
  - 1-mm position resolution
  - Maximum rate: 10^6 N per second for 100 pixels, 10^8 total
  - High magnetic fields
  - Low gamma sensitivity
- Backscattering Spectrometer
  - Detectors in vacuum
  - Low gamma sensitivity
  - Stability
- CNCS Spectrometer
  - Large area coverage > 20 m^2 when completed
  - Minimized TOF uncertainty
  - Recovery from Bragg peaks
  - Stability

Critical Requirements (4)

- ARCS and Sequoia Spectrometers
  - Large area coverage, ≈ 20 m^2
  - Detectors in vacuum
  - Recovery from Bragg peaks
  - 50% efficiency at 1 eV
  - Stability
- Fundamental Physics – part of experiment
- Triple Axis – He LPSDs

- Spin Echo – 30cm x 30cm at $3x10^7$ N per second
- Protein Crystallography
- Chemical Spectroscopy
- Polarized Neutron Instrument

Component 3: Detector Deficiencies

Table 4. Detector deficiencies for SNS instruments

Instrument	Parameter	Desired	Current	Comment
Liquids & Magnetism Reflectometers	Pixel area (cm^2)	0.01	0.02	0.02 is state of the art for ^3He gas detectors
	Maximum instantaneous rate/pixel (counts/s)	1.3×10^6	7×10^4	Beam attenuator will be necessary
	Maximum total instantaneous rate (counts/s)	1.2×10^8	1×10^6	Beam attenuator will be necessary
	Maximum time average rate/pixel (counts/s)	6.2×10^5	7×10^4	Beam attenuator will be necessary
	Maximum total time average rate (counts/s)	5.9×10^7	5×10^5	Beam attenuator will be necessary
	Transmission monitor pixel area (cm^2)	0.04	10	Characterize angular dependence of inc. beam
Powder Diffractometer	Neutron efficiency at 1 eV (%)	50	30	60% reduction in data rate
	Detector cost ($\$/m^2$)	150K	250K	Wavelength shifting modules will cover more area for the same cost
	Transmission detector maximum time average data rate (counts/s)	3.4×10^7	1×10^6	Reduce uncertainty in beam normalization
Engineering Instrument	Spatial resolution (mm)	0.1	1.0	Needed for residual stress depth profile measurements
	Transmission detector maximum time average data rate (counts/s)	5×10^7	1×10^6	Beam attenuator will be necessary
Single-Crystal Diffractometer	Spatial resolution (mm)	1	3	Unit cells limited to 30Å or less
	Transparent scintillator brightness (photons/neutron)	30,000	10,000	Needed for 1-mm resolution detectors
	Dynamic range (peak counts/background counts)	1×10^3	1×10^2	Needed for diffuse scattering studies
Inelastic Chopper Spectrometers	Spatial resolution (mm)	10	25	Q resolution limited by detectors for small samples
	Time resolution (μs)	1	5	Needed for high-resolution energy measurements
	Maximum instantaneous rate per detector (counts/sec)	2×10^7	7×10^4	Detectors will saturate, and inelastic data will be lost
Disordered Materials Diffractometer	Detection efficiency for 50eV neutrons (%)	20	5	Needed to measure atomic connectivity and defect distributions
Extended-Q SANS	Maximum total time average rate (counts/sec)	5×10^7	5×10^5	Needed to study weakly scattering biological samples
	Maximum parallax error (mm)	5	20	Q resolution limited by detector parallax

Critical Deficiencies

Instrument	Rate	Resolution	Efficiency
Liquids & Magnetism Reflectometers	x100	x2 Spatial (x250 Monitor)	
Powder Diffractometer	(x35 Monitor)		x1.6
Engineering Instrument	(x50 Monitor)	(x10 Residual Stress Detector, 1-D)	
Single Crystal		x10 Spatial	x3
Inelastic Chopper Spectrometers	x300 (Bragg peak)	x5 Time x2.5 Spatial	
Disordered Materials Diffractometer			x5
EQ-SANS	x100	x4 (Parallax)	

Component 4: Detector R&D

- No Standard Detector
  - Size varies from 4 cm^2 to 20 m^2
  - Efficiency requirements vary by 2 orders of magnitude
  - Maximum pixel rates vary by 4 orders of magnitude
  - Dominant requirement that drives detector selection can be:
    - Efficiency
    - Gamma sensitivity
    - Time resolution
    - Cost
    - Rate capability
    - Stability
    - Other?

Gas Detector R&D

- 2-D Gas Detectors needed for:
  - Low gamma sensitivity and high stability applications
  - New high rate applications lead to
  - Discrete pixels – 40,000 channels
    - Ionization mode ^{3}He
    - Multilayer GEM
    - Micromegas
  - Potential Applications
    - SANS Instruments
    - Spin echo Instruments
    - High pressure Instruments
    - Reflectometers

Scintillator Detector R&D

- Scintillator Detectors needed for:
  - Large area coverage with small pixels
  - High neutron detection efficiency
    - New bright, transparent scintillator
  - 1-μs time resolution
  - New readout schemes
    - Wavelength shifting fiber
    - Standard fiber
    - Anger camera
  - Potential Applications
    - Powder diffractometers
    - Engineering Instruments
    - Single Crystal Diffractometers
    - Disordered Materials Diffractometers

Proportional Counter R&D

- Proportional Counters needed for:
  - Low-cost large-area coverage
  - Stability
  - Low gamma sensitivity
  - New designs needed
    - Improved time resolution
    - Eliminate Bragg peak saturation
  - Potential applications
    - Backscattering spectrometers
    - Chopper spectrometers
    - Triple axis spectrometers

High Resolution Detector R&D

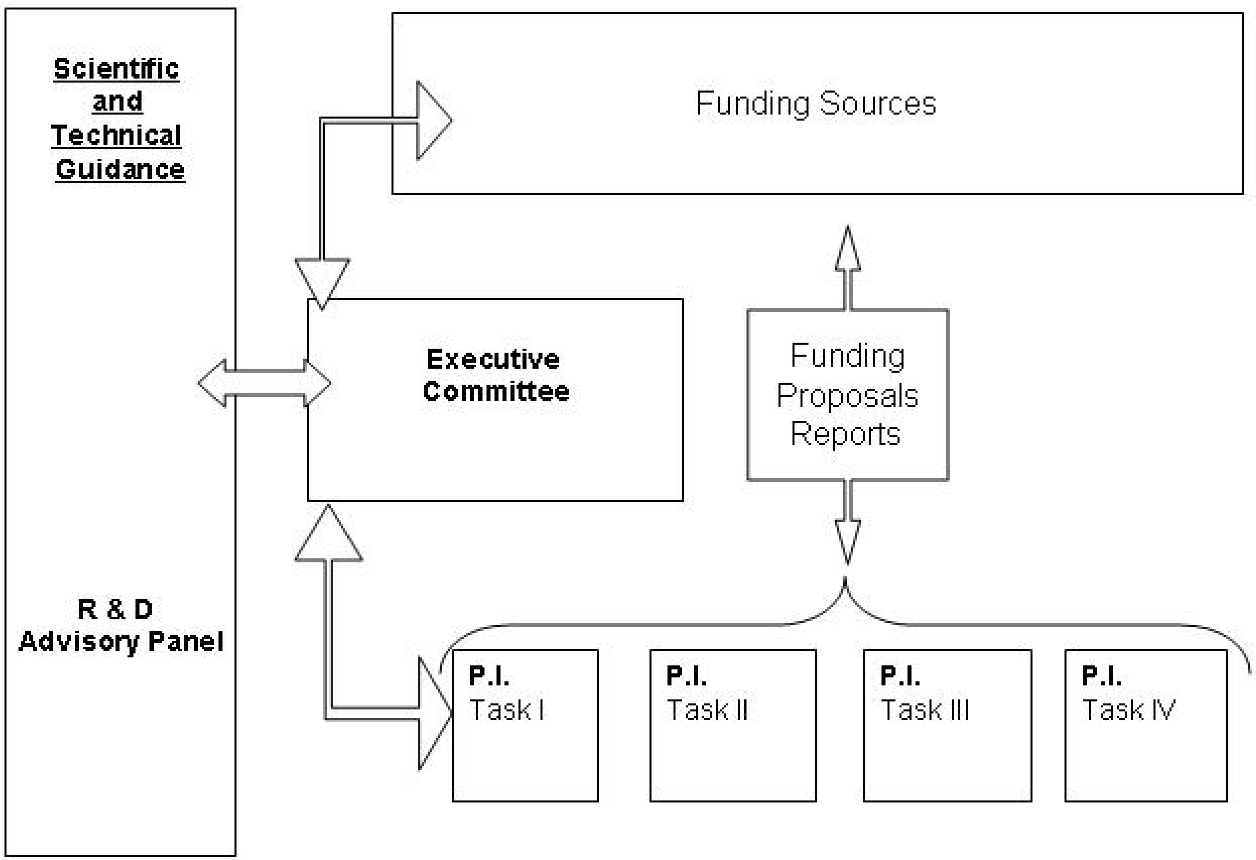
- High resolution detectors needed for:
  - Sub millimeter time dependent imaging
  - Small samples
  - Very high rate applications
  - Neutron beam characterization
  - Potential detector Research includes:
    - Semiconductor detectors
    - Microsphere detectors
    - Micromegas Detectors
    - Conversion foils
  - Potential Applications:
    - Residual stress measurements
    - Small samples on the High Pressure instrument
    - Transmission detectors

Component 5: National Plan for Neutron Detector Development

- Make sure neutron detector development meets the needs of the neutron users community
- Coordinate detector R&D within the U.S. and worldwide
- Prioritize the use of limited R&D resources

- Plan components:
  - Executive committee
  - Advisory panel
    - Neutron users (6)
    - Detector experts (6)
  - Roadmap
    - Whitepaper

Management Plan

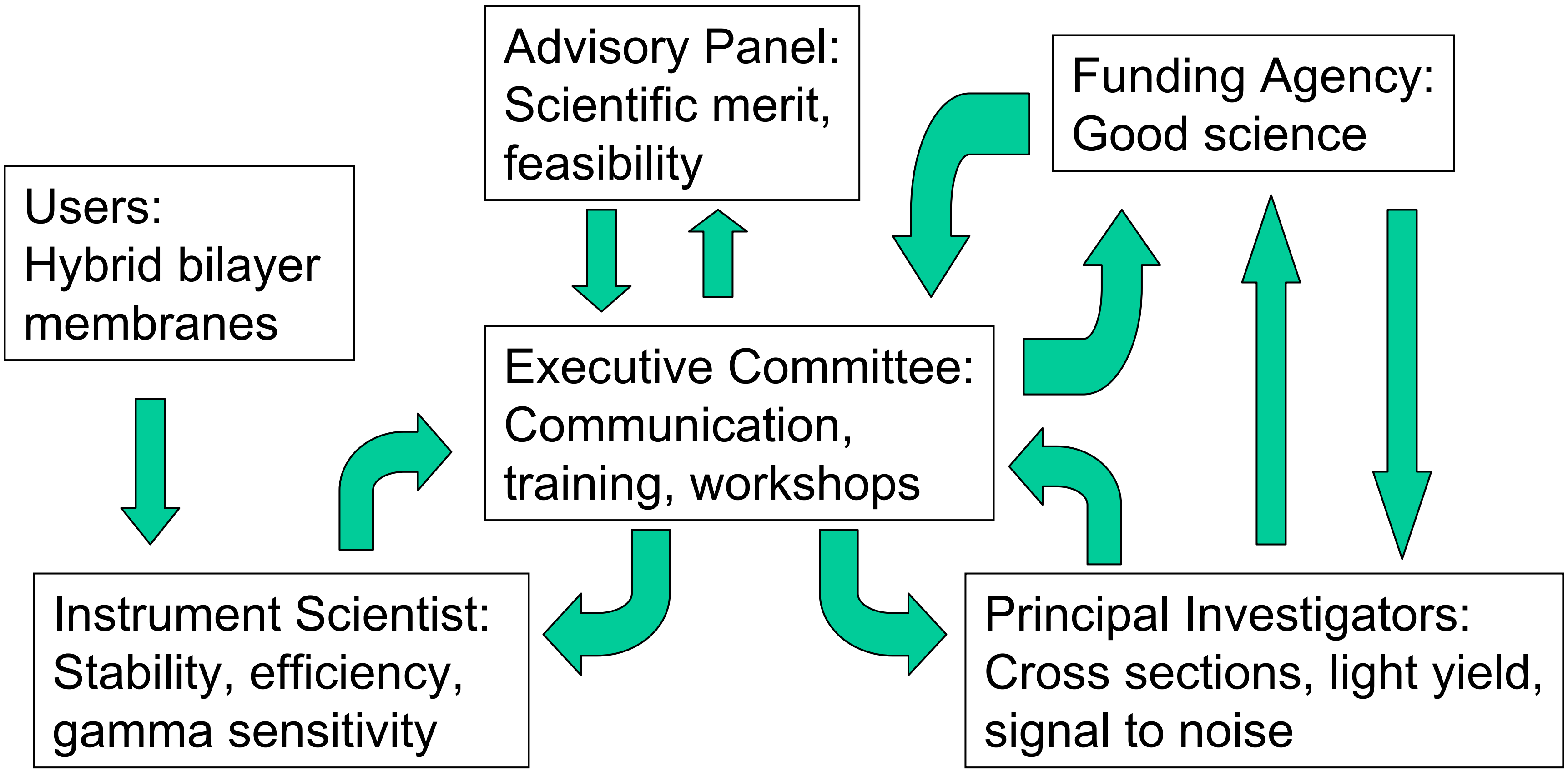


Executive Committee

- Current membership:
  - John Cameron – IUCF
  - Pat Gallagher – NIST
  - Veljko Radeka – BNL
  - Christine Hoffmann – SNS
  - Ron Cooper – SNS
- Responsibilities:
  - Supervise the plan
    - Maintain communication
    - Administer workshops
    - Periodic reviews
    - Request support from the advisory panel

Communication

- Diverse groups



Roadmap Components

- Advisory panel
  - International membership
  - Pool of expertise to support
    - Funding agencies
    - Executive committee
    - Detector PI's
  - Review proposals
- Roadmap
  - Whitepaper
  - Reference for proposals
  - Living document
  - Expand to include steady-state sources
  - Update as needed

Summary

- The roadmap consists of:
  - Science case
  - Instrument requirements
  - Detector deficiencies
  - Detector R&D
  - Management plan
- Maintained as a whitepaper
  - Living document
  - Reference for proposals
- Goal is a coordinated effort
  - Science focus
  - Communication
  - Guidance